Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

Date: September 26, 2023

To: District Ranger, Doublehead Ranger District, Modoc National Forest

Subject: White fir mortality within the Ursus Timber Sale area (FHP Report NE23-01)

Report Summary

Figure 1. White fir mortality within the Ursus Timber Sale area, 2023.

- White fir mortality has increased dramatically within untreated and recently thinned stands in the Ursus Timber Sale (11 to 50% mortality recorded during the 2023 aerial detection surveys).
- High stand density, moderate to high-risk site conditions for white fir, Heterobasidion root disease and persistent and extreme drought conditions are all contributing factors to observed tree mortality.
- Due primarily to fire exclusion, white fir now exists in dense and disease infected stands that are highly susceptible to large scale mortality events and stand replacing wildfire. These stand conditions are also contributing to ponderosa pine mortality and preventing pine regeneration.
- Several recently thinned units still appear to be overstocked with white fir and are experiencing elevated tree mortality.
- Fuel loading will continue to increase in some treated and all untreated stands due to excessive tree mortality, leaving the entire Lava Hazardous Fuels Reduction Project (HFRP) and surrounding areas at high-risk for stand replacing wildfire.
- More intensive thinning, sanitation and salvage are highly recommended throughout the project area to greatly reduce the abundance of white fir, reduce surface and ladder fuels and begin to restore fire-adapted pine dominated ecosystems.
- Residual stand density and marking guideline alternatives are provided in this report.

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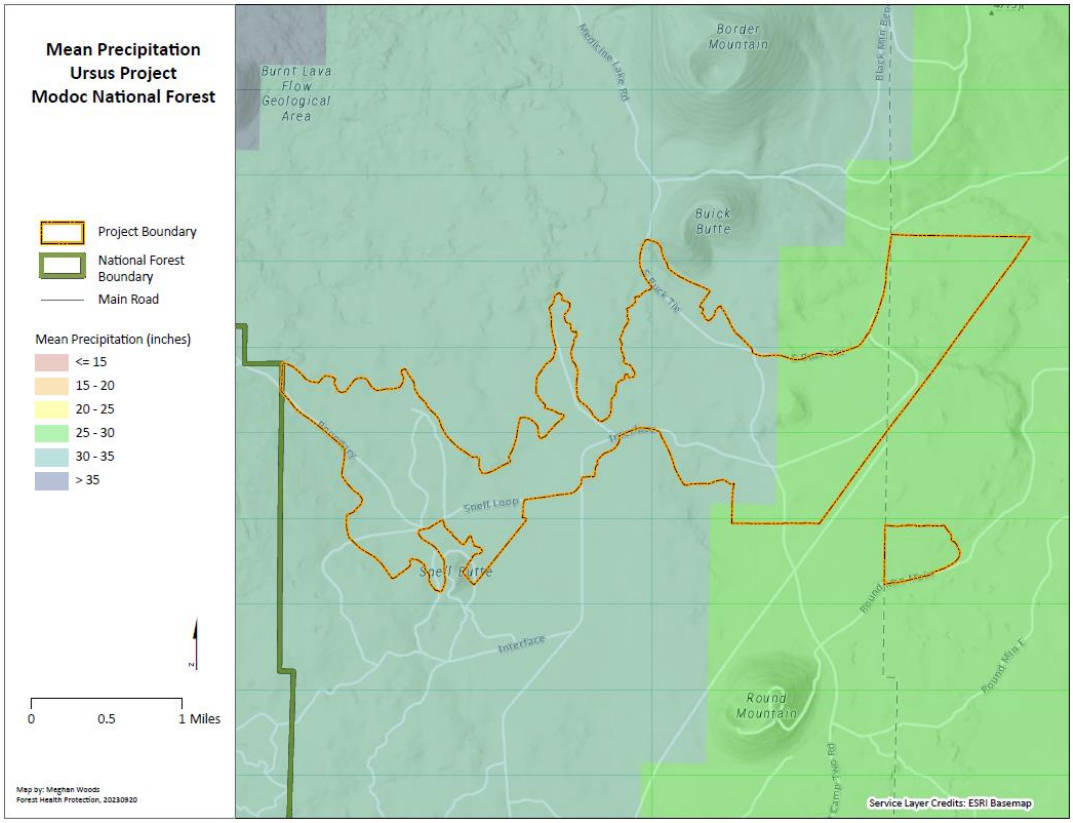
Background

At the request of Modoc National Forest timber staff, Danny Cluck, Forest Health Protection Entomologist, conducted a field evaluation of the Ursus Timber Sale on September 20, 2023. The objective of this visit was to assess the current level of white fir mortality, document existing stand conditions, and recommend silvicultural prescription changes to meet forest health objectives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions that reduce stand density, reduce ladder fuel, and provide for a more drought tolerant and fire resilient species composition.

Description of the project area

The Ursus TS is about 11 miles southeast of Medicine Lake at elevations ranging between 4,500 and 4,800 feet (Ursus TS is centered at 41.4561° N and 121.4606° W). Annual precipitation ranges between 25 and 35 inches (Figure 2). Forest cover is primarily native stands and a few pine plantations. Nearly all stands consist of ponderosa pine (*Pinus ponderosa*) and white fir (*Abies concolor*) with some areas of mixed conifer that include incense cedar (*Calocedrus decurrens*), sugar pine (*Pinus lambertiana*) and knobcone pine (*Pinus attenuata).* Plantations are mostly ponderosa pine with lesser amounts of incense cedar and white fir. Most forested areas are overly dense, have experienced elevated levels of tree mortality associated with insects, pathogens and drought and contain high numbers of standing and down dead trees.

Figure 2. Mean annual precipitation for the Ursus Timber Sale and surrounding area.



Ongoing mortality has resulted in an abundance of snags that will contribute greatly to coarse woody debris over the next decade (Figures 1 and 3).

Forest insect and disease conditions

Bark beetle activity observed during the site visit was primarily fir engraver beetle (*Scolytus ventralis*) attacking and killing white fir (Figure 3). White fir mortality was also associated with Heterobasidion root disease (caused by *Heterobasidion occidentale,* formerly referred to as S-type annosus root disease) (Figures 4 and 5) in many locations. The presence of root disease was suspected but not confirmed during the 2010 FHP evaluation of the Lava HFRP mostly due to limited survey time and limited tree mortality. Tree mortality and failure as well as harvest activity since 2010 has helped reveal evidence of root disease throughout the project area.

Figure 3. White fir mortality caused by fir engraver beetle, Ursus TS, 2023.

Figure 4. White fir root collar showing wood delamination on annual growth rings, a symptom of Heterobasidion root disease infection, Ursus TS, 2023.

Figure 5. Fruiting body (conk) of *H. occidentale* in stump, Ursus TS, 2023.

Western pine beetle (*Dendroctonus brevicomis*) was found killing small groups of second growth and individual old-growth ponderosa pines within high density stands (Figure 6).

Stand conditions and mortality related to recent and future climate trends

Most stands within the Ursus TS as well as other Lava HFRP project areas are extremely dense, based on relative stand density (rSDI) values, and have exhibited elevated levels of tree mortality caused by bark beetles and root disease, especially during periods of drought (Table 1, Figures 9

Figure 6. Mature ponderosa pine mortality (back of photo) caused by western pine beetle in unthinned wildlife emphasis stands, Ursus TS, 2023.

and 10). This mortality combined with high stand density has resulted in heavy fuel loading in many areas and a corresponding increase in potential fire behavior (Figure 11). The mortality resulting from the current drought suggests these areas do not support healthy stands of white fir over the long-term, especially when considering the potential impacts of longer, hotter droughts predicted by climate change models (Merriam 2022). This current mortality event is likely to persist and possibly increase until precipitation levels return to normal for successive years or white fir are significantly depleted by bark beetles and/or stand replacing wildfire.

White fir is now abundant on many sites that are considered moderate to high risk for mortality during drought periods (Figure 12). This species shift from shade intolerant pine species to shade tolerant white fir is primarily due to fire exclusion for the past 125+ years. Removal of pine species during past harvest entries has also contributed to this species shift in some areas.

Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within the Ursus TS area. No survey in 2020. 2023 acres and # dead tree values not available for this report. Preliminary mortality polygons suggest equal to greater tree mortality in 2023 compared to 2022.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2022	1,108	9.3	10,352	-3.04
2021	215	2.9	627	-4.23
2020	No survey			-1.45
2019	268	2.9	768	0.99
2018	109	3.0	324	-0.83
2017	178	2.7	483	3.03
2016	1,457	1.5	2,211	-1.32
2015	1,187	2.7	3,239	-3.34
2014	4	2.0	8	-3.56
2013	21	3.4	71	-2.16
2012	29	1.2	34	-3.04

[1] California Divisions 2 and 3 encompass most of northeastern California.
[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Figure 9. Number of dead trees per acre from 2013 to 2022 in the Ursus TS area. No survey in 2020 and 2023 trees/acre data not available. There are likely more dead trees/acre than depicted on this map (see Fig. 10).

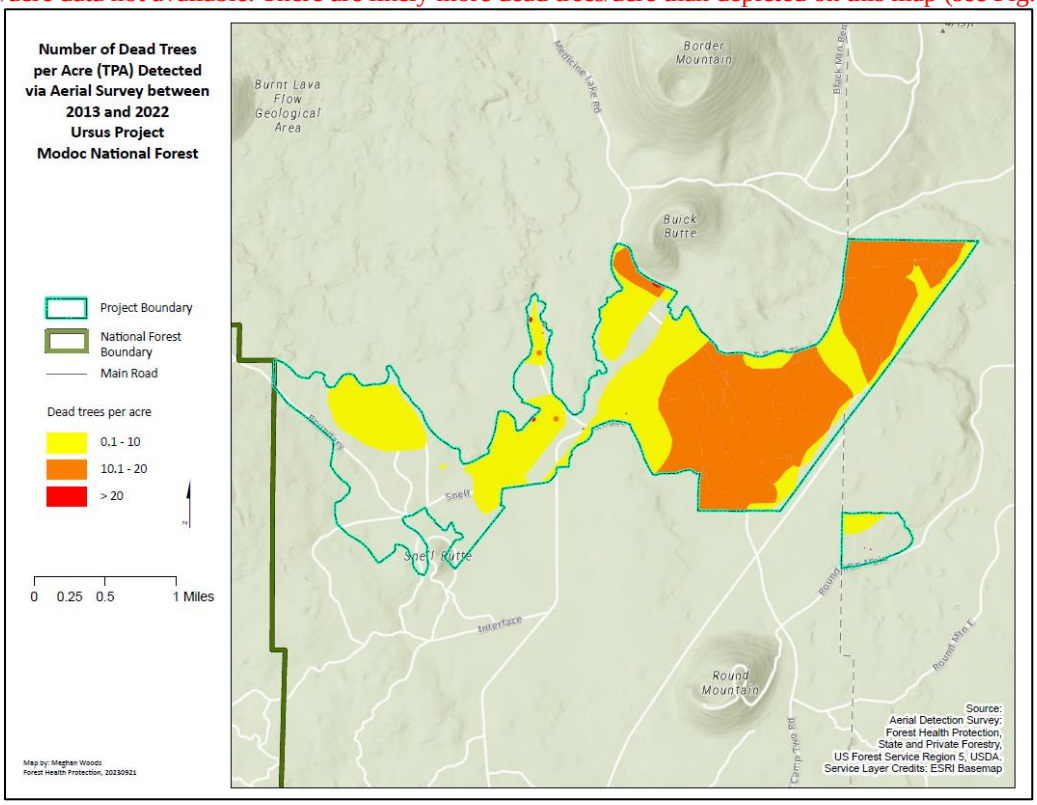

Number of Dead Trees per Acre (TPA) Detected via Aerial Survey between 2013 and 2022
Ursus Project
Modoc National Forest
Project Boundary
National Forest Boundary
Main Road
Dead trees per acre
0.1 - 10
10.1 - 20
> 20
0 0.25 0.5 1 Miles
Burnt Lava Flow Geological Area
Border Mountain
Buck Butte
Snell Butte
Round Mountain
Source: Aerial Detection Survey: Forest Health Protection, State and Private Forestry, US Forest Service Region 5, USDA. Service Layer Credits: ESRI Basemap

Figure 10. Areas of mapped tree mortality and severity within and adjacent to the Ursus TS area, 2023.

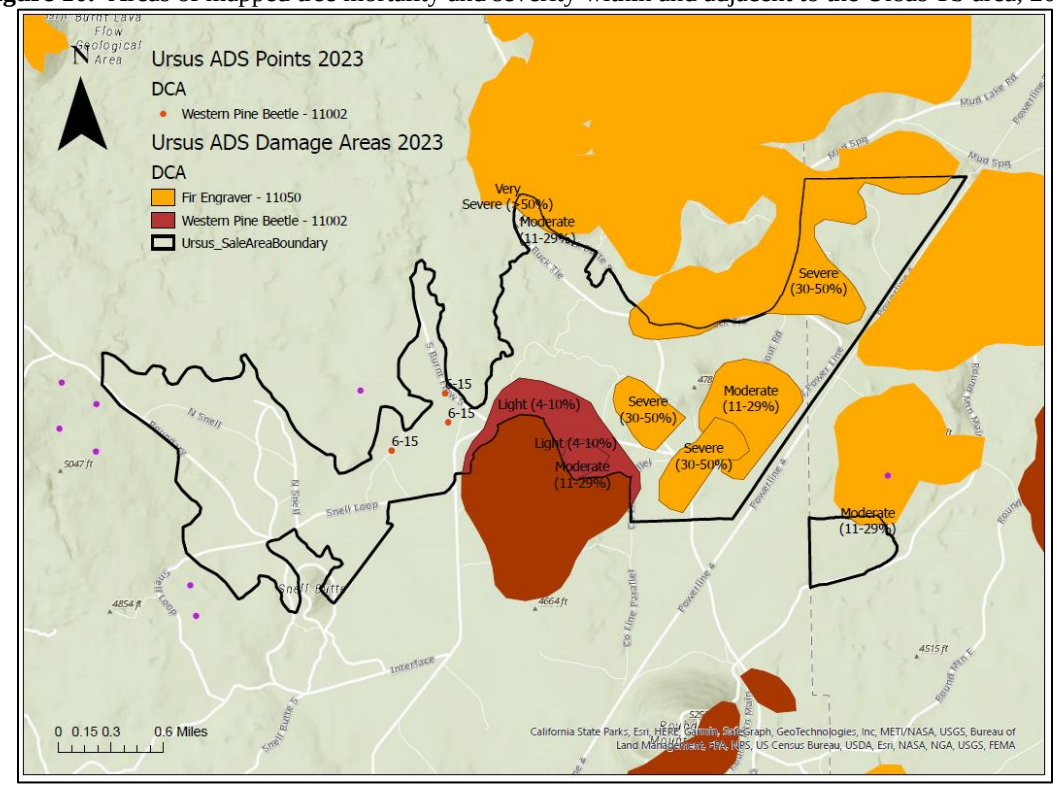


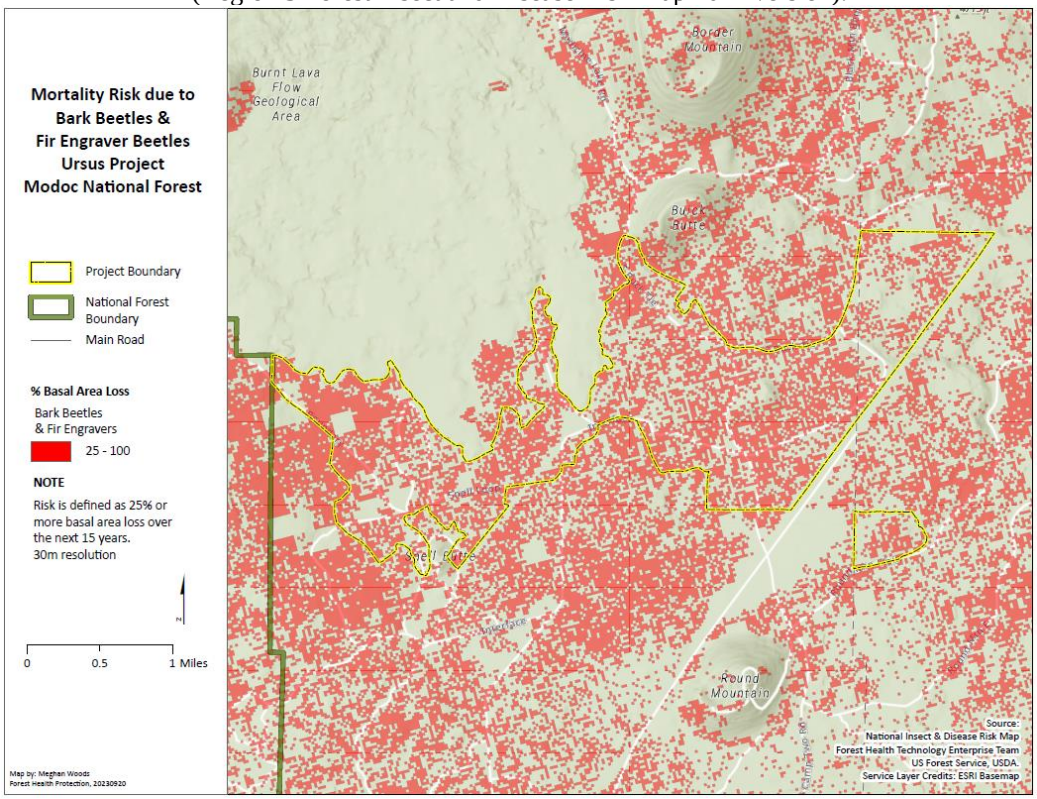
Figure 11. Standing and downed dead trees creating heavy fuel loads, Ursus TS, 2023.

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the Ursus TS area, high stand density, prolonged drought, Heterobasidion root disease and moderate to high-risk site conditions due to low average annual precipitation are all contributing factors in declining tree health and mortality.

All areas within the Ursus TS boundaries receive less than 35 inches of annual precipitation and about 1/3 receive less than 30 inches. This is marginal to below what is generally required for healthy white fir forests to exist over the long-term. Therefore, even at the lowest stocking levels, white fir growing on these sites are at a higher risk for fir engraver beetle-caused mortality during periods of drought.

The distribution of both white fir and white fir mortality are strongly influenced by the mean annual precipitation. The lower limit of precipitation in the natural range of white fir is about 20

Figure 12. Risk of bark beetle-caused tree mortality based on precipitation, stand density and average tree diameter (Region 5 Forest Insect and Disease Risk Map 2012 version).



inches (Fowels, H.A. 1965). The isohyetal map of mean annual precipitation provided in this report (Figure 1) can be used to rate the risk of white fir mortality (Schultz 1994, FHP Report 94-2). This risk rating was developed prior to the current long-term dry period that began in 2000. The past 23 years have challenged several stocking thresholds for pine species, resulting in high levels of bark beetle activity in what were thought to be resilient stand conditions (Fettig et al 2021). It is very likely that the risk thresholds for white fir presented below, are not adequate for current and future climate conditions. Annual precipitation levels that previously identified low and moderate mortality risk may need to be changed to moderate to high respectively based on recent observed mortality across NE California.

Low risk: 40+" annual precipitation **(~ 0% of Ursus TS)**.
These areas easily support stands of white fir. Mortality will be low, even during drought periods. Thinning will increase the rate of tree growth but will show only slight differences in tree mortality.

Medium Risk: 30-40" of annual precipitation **(~65% of Ursus TS)**.
Stands in these areas often have a high percentage of white fir that may achieve a considerable age and size. Prolonged drought may cause mortality of 5-10% of the stems. Periodic thinning which concentrates on removing white fir ingrowth will lower mortality by maintaining a more sustainable amount of biomass, as well as promoting a more stable mixed species stand.

High Risk: 25-30" of annual precipitation **(~35% of Ursus TS)**.
In the absence of fire, these areas have stands which are dominated by densely stocked, small diameter white fir. The species distribution by age class shows an increase in the relative percentage of white fir in these stands following fire suppression. Prolonged drought may cause mortality in excess of 50% of the stems. The risk of mortality can be lowered by thinning to a wide spacing prior to the onset of drought, and by promoting a mix of species that are native to the site. *Note: this zone also includes larger diameter white fir that have established following fire suppression. These trees should be targeted for removal as well as smaller diameter white fir to establish and maintain a fire-adapted pine system.*

Extreme risk: 20-25" of annual precipitation **(~ 0% of Ursus TS).**
In some cases, the shade tolerant trees may live long enough to achieve an intermediate or co-dominant crown position. Prolonged drought may cause mortality of 80-85% of the stems. In stands where the total stocking of both overstory and understory is high, mortality may also occur in the pines. The risk of mortality may be lowered by managing groups of pine at wide spacing.

A white fir levels of growing stock study conducted by Cochran (1998) on the Deschutes and Fremont National Forests between 1983 and 1995 provides some additional information to consider when managing white fir in lower precipitation areas. Plots were thinned in 1982 and again in 1985 to a residual stand density index (SDI) of 112, 168, 224 or 280. These corresponded to growing stock levels of 20, 30, 40 or 50 percent of normal density. Elevations for his study plots ranged from 4,500 to 5,900 feet with average annual precipitation ranging from 16 to 31 inches. A general drought prevailed over the study areas from the late 1970's to the mid 1990's and mortality between 1991 and 1995 destroyed the study. Mortality on Blocks 2, 3 and 4 of the study was attributed to fir engraver beetles. Mortality from fir engraver beetles appeared to increase with

increasing stand densities and was above acceptable levels even at the lowest stand density (20 percent of density considered normal for white fir).

From Cochran 1998:

"Healthy stands of white fir grow very rapidly, produce a dense crown cover, and are visually pleasing. These results, however, raise doubts about growing white fir stands on sites with mean annual precipitation rates below 32 inches even if stand densities are kept very low. The four widely scattered stands represented in this study apparently grew well for more than 60 years and reached commercial size before severe mortality occurred. Where significant amounts of white fir are present, managers need the ability to manipulate stand composition to minimize mortality. Future stands on similar sites should have a large component of ponderosa pine and should be managed by using ponderosa pine stocking guides (Cochran and others 1994). These density levels would allow the individual fir trees, intermingled with pine, to reach commercial size at fairly young ages. If drought, disease outbreaks, or severe insect infestations occur, the white fir could be removed, leaving ponderosa pine on the site. Ponderosa pine quickly responds to new growing space even at old ages and would quickly take advantage of the available site resources. Ferrell (1978) reports that trees under high moisture stress (-20 bars dawn xylem pressure or higher negative pressures) for protracted summer periods are more susceptible to successful fir engraver attacks than are trees under less stress. If prolonged droughts are forecast, removal of most of the white fir on drier sites may be advisable. This would prevent the buildup of fir engraver populations that could migrate to moist sites and inflict heavy damage where, historically, white fir has survived dry periods."

In a Warner Mountain study by Egan et al (2010), the density of fir engraver beetle-caused tree mortality was greater in unthinned versus thinned mixed conifer stands but the percentage of mortality relative to available host trees was similar. This further suggests that white fir growing in high-risk sites (based on average annual precipitation) are susceptible to drought and fir engraver-beetle caused mortality regardless of stocking levels.

From Egan et al (2010):

"Our findings varied in mixed conifer areas as the density of, but not percent, FEN (fir engraver beetle)-caused mortality was reduced in thinned areas. These results do not support the use of thinning to reduce percent mortality or the relative number of residual white fir trees susceptible to FEN-caused mortality during times of drought. Conversely, this study does support the efficacy of thinning to reduce the density of mortality or absolute number of beetle-killed trees in mixed conifer stands exposed to drought conditions. The density of residual white fir host and elevation (likely a proxy for water availability) were important factors associated with white fir mortality in our study. These findings indicate thinning effectiveness in reducing fir mortality was directly proportional to the amount of post-treatment density white fir retained. Thus, our findings support discriminating against residual fir and retaining a greater pine component, similar to historic compositions (Vale, 1977), during thinning treatments to reduce the density of FEN-caused mortality even during periods of drought."

Predicted climate change is likely to impact trees growing in the Ursus Timber Sale and surrounding areas that include the Lava HFRP over the next 100 years. Although no Modoc National Forest specific climate change models are available at this time, there is a consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam, *Modoc National Forest Climate Change Trend Summary 2022*). The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future droughts through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Considerations for thinning treatments

The best strategy to decrease the amount of additional mortality is to reduce stand density through thinning in untreated stands and, depending on existing stocking and species composition, to further reduce density in previously treated stands. Thinning will increase the health and vigor of residual trees by reducing competition for limited soil moisture (Fettig et al. 2007). Mechanical thinning is recommended for the initial treatment to reduce stand density and ladder fuels that will allow long-term maintenance with prescribed fire without causing excessive mortality of residual trees.

Low to mid elevation white fir/ponderosa pine (mixed conifer) stands should be managed as eastside pine as much as possible. This includes all white fir dominated stands with a significant ponderosa pine component. This will likely require a change from the current Sierran mixed conifer stand typing in many areas to eastside pine, or at least managing mixed conifer for the pine component, better representing historic species compositions and desired future conditions. Having the ability to significantly reduce stand density and the abundance of white fir is critical to successful ecological restoration in this project area. Thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality for many years.

The bark beetle limiting SDI (Oliver 1995, Zhang et al., 2013 and 2019) could be used as the SDImax for eastside pine on upper slope positions and drier sites and SDImax of 450 (Long and Shaw 2005) could be used for sites that receive slightly more precipitation, occur on more northerly slopes or on lower slope positions, including more xeric Sierran mixed conifer stands. If areas of white fir exist that appear relatively healthy and there is evidence of significant white fir presence pre-fire exclusion (old trees, logs and stumps), an SDImax of 550 could be considered (Long and Shaw 2012). Table 2 provides relative SDI alternatives for the remaining Ursus TS treatment units.

This level of stand density reduction is supported by the latest research showing that Sierra Nevada mixed conifer stands seldom, if ever, exceeded rSDI of 60% (zone of imminent mortality) and most often maintained densities below the onset of competition (rSDI of 25%) (North et al 2022). In addition, recent analysis of several bark beetle outbreaks in yellow pine dominated forests

Table 2. Alternative residual stand density considerations for Ursus TS thinning units

Unit #	Current SDI	Current expected post-treatment SDI	Recommended post-treatment SDI range	rSDI range*
2	354	168	90 - 145	25 – 40%
4	340	139	90 - 145	25 – 40%
11	446	232	90 - 145	25 – 40%
112	514	311	112 - 182	25 – 40%
300	320	193	90 - 145	25 – 40%
340	314	139	90 - 145	25 – 40%
342	314	139	90 - 145	25 – 40%
345	181	112	90 - 145	25 – 40%
460	522	251	112 - 182	25 – 40%
480	522	251	112 - 182	25 – 40%
490	522	251	112 - 182	25 – 40%
560	522	265	112 - 182	25 – 40%
700	200	101	90 - 145	25 – 40%
760a	279	113	90 - 145	25 – 40%
760b	200	101	90 - 145	25 – 40%
770	271	160	90 - 145	25 – 40%
900a	314	139	90 - 145	25 – 40%
900b	522	250	112 - 182	25 – 40%

*rSDI based on SDImax of 365 for eastside pine and 450 for pine dominated Sierran mixed conifer

suggest much lower stocking levels are needed to minimize bark beetle activity. Specifically, their analysis indicated that the resistance levels suggested in earlier studies at 200 SDI (55% of the bark beetle limiting SDI of 365) were insufficient to provide for either a high-level, or moderate level, of resistance when challenged by severe beetle pressure levels. Overall, results indicated substantially lower stand density levels <100 SDI (27% of bark beetle limiting SDI) are needed to promote high-level resistance, and <150 SDI (41% of bark beetle limiting SDI) to promote moderate-level resistance, to severe *Dendroctonus* spp. population pressure that has been documented during primarily dry time segments from 2000-2018 (Fettig et al 2021). These resistance thresholds for low, moderate, and high protection against mortality during outbreaks, in terms of tree diameter and spacing, are listed in Appendix B. Incorporating these different stocking levels into a heterogeneous treatment of existing ponderosa pine stands should provide a higher level of protection from drought and bark beetles while allowing for successful reintroduction of low intensity prescribed fire.

When planning thinning treatments, it should be recognized that the target stand density and species composition is an average to be applied across the landscape and some variability may be desired. Individual high-value trees, such as mature pines, and drier areas dominated by ponderosa pine should benefit by having the stocking reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. However, the preferential removal of white fir should be the

primary means to achieve residual stand density targets in the Ursus TS. Appendix A provides an example of a marking guideline that could be modified to achieve desired stand conditions.

The presence of Heterobasidion root disease in white fir should be considered when developing silvicultural prescriptions. Root diseased white fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees will likely lead to higher levels of mortality over the long-term, reducing large tree canopy cover and increasing fuels. Leaving these trees will also reduce opportunities in the near term for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.
The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees (based on crown condition and vigor). Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, incense cedar and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

It is recommended that a registered borate compound be applied to all freshly cut pine stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* if there are known or suspected root disease pockets with 1/3 mile of treatment units. Treatment of white fir stumps is a low priority unless a treatment unit contains mostly healthy, and presumably disease free, trees. Stumps created along roadways and infrastructure are a higher priority for treatment regardless of species. Please refer to the new borate treatment recommendation table (Appendix C).

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-708-2770.

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Appendix A: Example of marking guidelines that could be modified to meet objectives for Ursus TS

Possible Marking Guideline Example (needs localized fine tuning)

Mechanical Variable Thinning (ITM)

Mark cut trees ≥10" dbh and <30" dbh in blue tracer paint until desired BA/ac is attained as follows:

Target BA

Eastside Mixed Conifer (Pine Dominant) – **80 ft²/ac. average.** (60 ft²/ac average on dry/pure pine sites and 100 ft²/ac average on moist/mixed conifer sites i.e., North aspects, lower slopes etc.).

Eastside Mixed Conifer (White Fir Dominant) – **100 ft²/ac. average.** (120 ft²/ac. average on moist/mixed conifer sites, i.e., North aspects, lower slopes etc.).

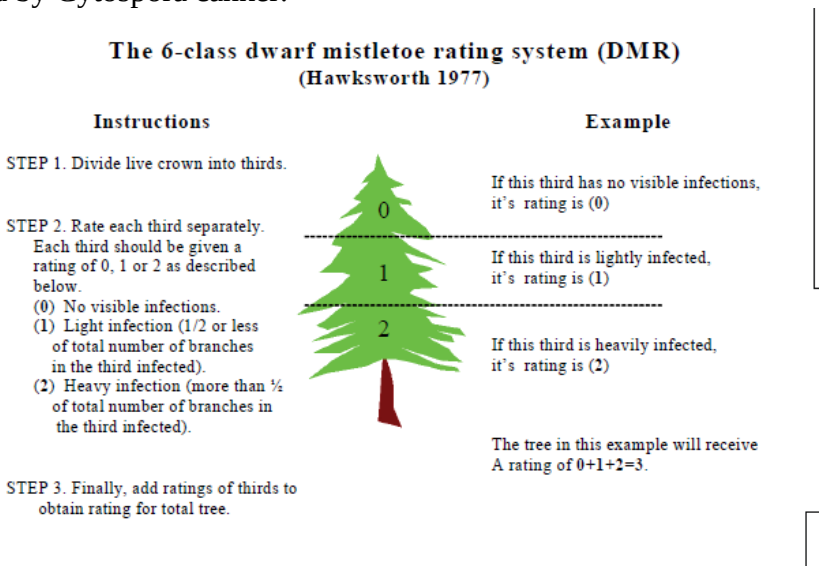
Species priority

Conifers shall be marked as "CUT" in the following order of priority: **White Fir (WF), Ponderosa Pine (PP), Incense Cedar (IC) and Sugar Pine (SP)**

Marking Guidelines

CUT WF/PP/SP that have any combination of boring dust or frass, pouch fungus conks and/or current woodpecker activity present over at least 1/3 of the bole circumference. (Exclude woodpecker activity when restricted to the lower 2 to 3 feet of the bole). *Unless needed for snag retention.*

CUT WF/PP that are infected dwarf mistletoe (DMT). In areas of heavy DMT infection, select trees with severe infection (Hawksworth Rating ≥4), mistletoe cankers, or trees with any signs of infection in upper 1/3 of the crown. See diagram below. White fir DMT may be associated with branch flagging caused by Cytospora canker.


The 6-class dwarf mistletoe rating system (DMR)
(Hawksworth 1977)
Instructions
Example
STEP 1. Divide live crown into thirds.
STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.
(0) No visible infections.
(1) Light infection (1/2 or less of total number of branches in the third infected).
(2) Heavy infection (more than ½ of total number of branches in the third infected).
STEP 3. Finally, add ratings of thirds to obtain rating for total tree.
0
1
2
If this third has no visible infections, it's rating is (0)
If this third is lightly infected, it's rating is (1)
If this third is heavily infected, it's rating is (2)
The tree in this example will receive A rating of 0+1+2=3.

CUT WF with live crown ratios less than 30%, faded or rounded crowns, ragged crowns (multiple dead branches and/or poor needle retention) and/or dead tops.

CUT WF within 50 ft large diameter pine (>24" dbh) regardless of condition.

White fir with dead top

White fir with ragged crown

White fir with rounded top and ragged crown

White fir with branch flagging caused by Cytospora and DMT

** Retain occasional trees (1 per 3 acres) with enhanced wildlife habitat value, large trees with: large diameter branches that provide potential resting platforms, large mistletoe brooms, multiple tops, cavities, dead tops and/or decay. **

**** DO NOT MARK****

- **LEAVE** trees that are greater than or equal to **30" dbh**.
- **LEAVE** trees that designate property lines/corners, e.g., blazed or posted with National Forest boundary signs or yellow K-tags that reference the location of section corners (Bearing or witness trees).
- **LEAVE** trees of the same species growing close together (1 foot or less apart at the base), either leave both or cut both trees. These trees may have grafted roots, interlocked crowns or one-sided crowns and lack wind-firmness.
- **LEAVE** all IC and SP.

Appendix B: Stand density table for ponderosa pine

Tree-Level SDI Thresholds and Spacing Equivalence to Promote Bark Beetle Resistance within Ponderosa Pines

Note: Spacing Targets Should be Adjusted to Account for Post-Treatment Vegetation Growth throughout the Time Horizon that Resistance is Needed

Based on Meta-Analysis of data from 662 plots covering >60,000 trees 'challenged' by Dendroctonus spp. populations

Tree Diameter	**Minimum Protection: 200 SDI** — Assuming a Severe *Dendroctonus* spp. Outbreak: *48% probability of High-Degree Resistance (>90% pine survival)* *69% probability of Moderate-Degree Resistance (>70% pine survival)*			**Moderate Protection: 150 SDI** — Assuming a Severe *Dendroctonus* spp. Outbreak: *64% probability of High-Degree Resistance (>90% pine survival)* *84% probability of Moderate-Degree Resistance (>70% pine survival)*			**High Protection: 100 SDI** — Assuming a Severe *Dendroctonus* spp. Outbreak: *85% probability of High-Degree Resistance (>90% pine survival)* *95% probability of Moderate-Degree Resistance (>70% pine survival)*			Tree Diameter
(inches)	Trees/acre	Spacing	BA/acre	Trees/acre	Spacing	BA/acre	Trees/acre	Spacing	BA/acre	(inches)
4	870	7	76	653	8	57	479	10	42	4
5	608	8	83	456	10	62	335	11	46	5
6	454	10	89	341	11	67	250	13	49	6
7	355	11	95	266	13	71	195	15	52	7
8	286	12	100	215	14	75	157	17	55	8
9	237	14	105	178	16	78	130	18	58	9
10	200	15	109	150	17	82	110	20	60	10
11	172	16	113	129	18	85	94	21	62	11
12	149	17	117	112	20	88	82	23	64	12
13	131	18	121	98	21	91	72	25	67	13
14	117	19	125	87	22	93	64	26	69	14
15	104	20	128	78	24	96	57	28	70	15
16	94	22	131	71	25	98	52	29	72	16
17	85	23	135	64	26	101	47	30	74	17
18	78	24	138	58	27	103	43	32	76	18
19	71	25	141	54	29	105	39	33	77	19
20	66	26	143	49	30	108	36	35	79	20
21	61	27	146	46	31	110	33	36	80	21
22	56	28	149	42	32	112	31	37	82	22
23	53	29	152	39	33	114	29	39	83	23
24	49	30	154	37	34	116	27	40	85	24
25	46	31	157	34	36	117	25	42	86	25
26	43	32	159	32	37	119	24	43	88	26
27	41	33	161	30	38	121	22	44	89	27
28	38	34	164	29	39	123	21	45	90	28
29	36	35	166	27	40	125	20	47	91	29
30	34	36	168	26	41	126	19	48	93	30
31	33	37	171	24	42	128	18	49	94	31
32	31	38	173	23	43	130	17	51	95	32
33	29	38	175	22	44	131	16	52	96	33
34	28	39	177	21	45	133	15	53	97	34
35	27	40	179	20	47	134	15	54	98	35

Contact Joel Egan, FHP Group Leader, joel.egan@usda.gov, 406-329-3278 for details on using this chart

Table provides the trees/acre, spacing, and basal area equivalence across constant 200, 150, or 100 SDI levels, respectively

Priorities for stump borate treatments to prevent Heterobasidion Root Disease (HRD) v.4.5
Contact your Forest Health Protection Entomologist or Plant Pathologist for assistance

USFS Region 5 - BORATE STUMP TREATMENT PRIORITY BY FOREST CONDITION and HARVEST ACTIVITY			
Priority	**HARVEST ACTIVITY in FOREST TYPE and CONDITION**	***TREAT WHICH STUMPS?**	**WHY**
Very Low	Salvage high severity burn (nearly all trees killed); plant	NONE	Little connectivity with seedling roots; Most dead roots get infected with competing organisms before seedling roots contact them
Very Low	Clearcut PP/JP, true fir or mixed conifer; any location including roadsides and powerline corridors	NONE	Very low probability of new establishing new infection centers
Very Low	Thin true fir which has widespread light to heavy HRD	NONE	Borates do not cure existing infection
Low	Thin PP/JP with no current or historic pine HRD within 1700 feet	NONE	Very low atmospheric spore concentration
Low	Thin PP/JP in mixed species stands; few >14" PP/JP stumps	NONE	Small pine stumps don't create HRD centers; small roots get infected fast with competing organisms
Low	Thin PP/JP in mixed species stands; few pine-to-pine root contacts	NONE	HRD won't spread from stumps that don't have root contact w/ live trees
Low	Thin Doug-fir; incense cedar; sugar pine; other conifers	NONE	Little evidence of HRD problems
Moderate	Salvage low to moderate severity burn (scattered remaining green trees)*	Consider treating >14" PP/JP and > 24" juniper stumps having possible root contact with high-value PP/JP. Treat true fir stumps in stands with no fir HRD	Borates do not cure existing infections. Treating pine stumps near high-value pine trees can protect residual pine from HRD. Large juniper stumps may facilitate spread to adjacent pines.
High	Any cutting, PP/JP, true fir in roadside and powerline corridors (including hazard tree removal and salvage* in low to moderate severity burns)	Treat all PP/JP and > 24" juniper stumps and true fir stumps >14"	Borates prevent infection; lower tolerance for new HRD centers in these areas. Large juniper stumps may facilitate spread to adjacent pines.
High	Thin PP/JP in mixed species stands; many >14" PP/JP stumps and pine-to-pine root contacts; pine HRD within 1700 feet (or distance to nearest HRD not known)	>14" PP/JP stumps (also >24" juniper stumps if present)	Borates prevent infection. Large juniper stumps may facilitate spread to adjacent pines.
High	Thin true fir with no HRD	> 14" fir stumps	Borates prevent infection
Very High	Thin PP/JP; many >14" stumps; pine HRD within 1700 feet (or distance to nearest HRD not known)	>14" PP/JP stumps	Every stump can start HRD centers
Very High	Recreation and Administrative Sites	>3" conifer stumps	Zero tolerance for new HRD centers in these areas means treating smaller stumps of all conifer species
Very High	Thin giant Sequoia groves; treat conifer stumps within 1700 feet of monarch giant sequoia trees	>3" conifer stumps	Zero tolerance for new HRD centers in these areas means treating smaller stumps of all conifer species

* No need to treat stumps of trees with no needles or stumps of trees killed by fire >18 months earlier